CLASSIFICATION OF NON-HEAT GENERATING OUTDOOR OBJECTS IN THERMAL SCENES FOR AUTONOMOUS ROBOTS

William L. Fehlman II

College of William & Mary, Department of Applied Science, 2008
Field: Nondestructive Evaluation, Degree: PhD

Advisor: Mark Hinders, Professor of Applied Science

Abstract

This dissertation describes a physics-based adaptive Bayesian pattern classification model that uses a passive thermal infrared imaging system to automatically characterize non-heat generating objects in unstructured outdoor environments for mobile robots. In the context of this research, non-heat generating objects are defined as objects that are not a source for their own emission of thermal energy, and so exclude people, animals, vehicles, etc. The resulting classification model complements an autonomous bot's situational awareness by providing the ability to classify smaller structures commonly found in the immediate operational environment. Since GPS depends on the availability of satellites and onboard terrain maps which are often unable to include enough detail for smaller structures found in an operational environment, bots will require the ability to make decisions such as "go through the hedges" or "go around the brick wall." A thermal infrared imaging modality mounted on a small mobile bot is a favorable choice for receiving enough detailed information to automatically interpret objects at close ranges while unobtrusively traveling alongside pedestrians. The classification of indoor objects and heat generating objects in thermal scenes is a solved problem. A missing and essential piece in the literature has been research involving the automatic characterization of non-heat generating objects in outdoor environments using a thermal infrared imaging modality for mobile bots. Seeking to classify non-heat generating objects in outdoor environments using a thermal infrared imaging system is a complex problem due to the variation of radiance emitted from the objects as a result of the diurnal cycle of solar energy. The model that we present will allow bots to "see beyond vision" to autonomously assess the physical nature of the surrounding structures for making decisions without the need for an interpretation by humans.

The approach described here is an application of Bayesian statistical pattern classification where learning involves labeled classes of data (supervised classification), assumes no formal structure regarding the density of the data in the classes (nonparametric density estimation), and makes direct use of prior knowledge regarding an object class's existence in a bot's immediate area of operation when making decisions regarding class assignments for unknown objects. We have used a mobile bot to systematically capture thermal infrared imagery for two categories of non-heat generating objects (extended and compact) in several different geographic locations. The extended objects consist of objects that extend beyond the thermal camera's field of view, such as brick walls, hedges, picket fences, and wood walls. The compact objects consist of objects that are within the thermal camera's field of view, such as steel poles and trees. We used these large representative data sets to explore the behavior of thermal-physical features generated from the signals emitted by the classes of objects and design our Adaptive Bayesian Classification Model. We demonstrate that our novel classification model not only displays exceptional performance in characterizing non-heat generating outdoor objects in thermal scenes but it also outperforms the traditional KNN and Parzen classifiers.